Lunar Water Resource Demonstration (LWRD)

ex luna, aqua

Tony Muscatello

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Major Contributors

- ASRC: Tracy Gibson, Steve Perusich, Steve Parks, and Kyle Weis
- NASA: Jeremy Parr, Mark Nurge, Dale Lueck, Janine Captain, Curtis Ihlefeld, Tom Moss, Jackie Quinn, and Bill Larson

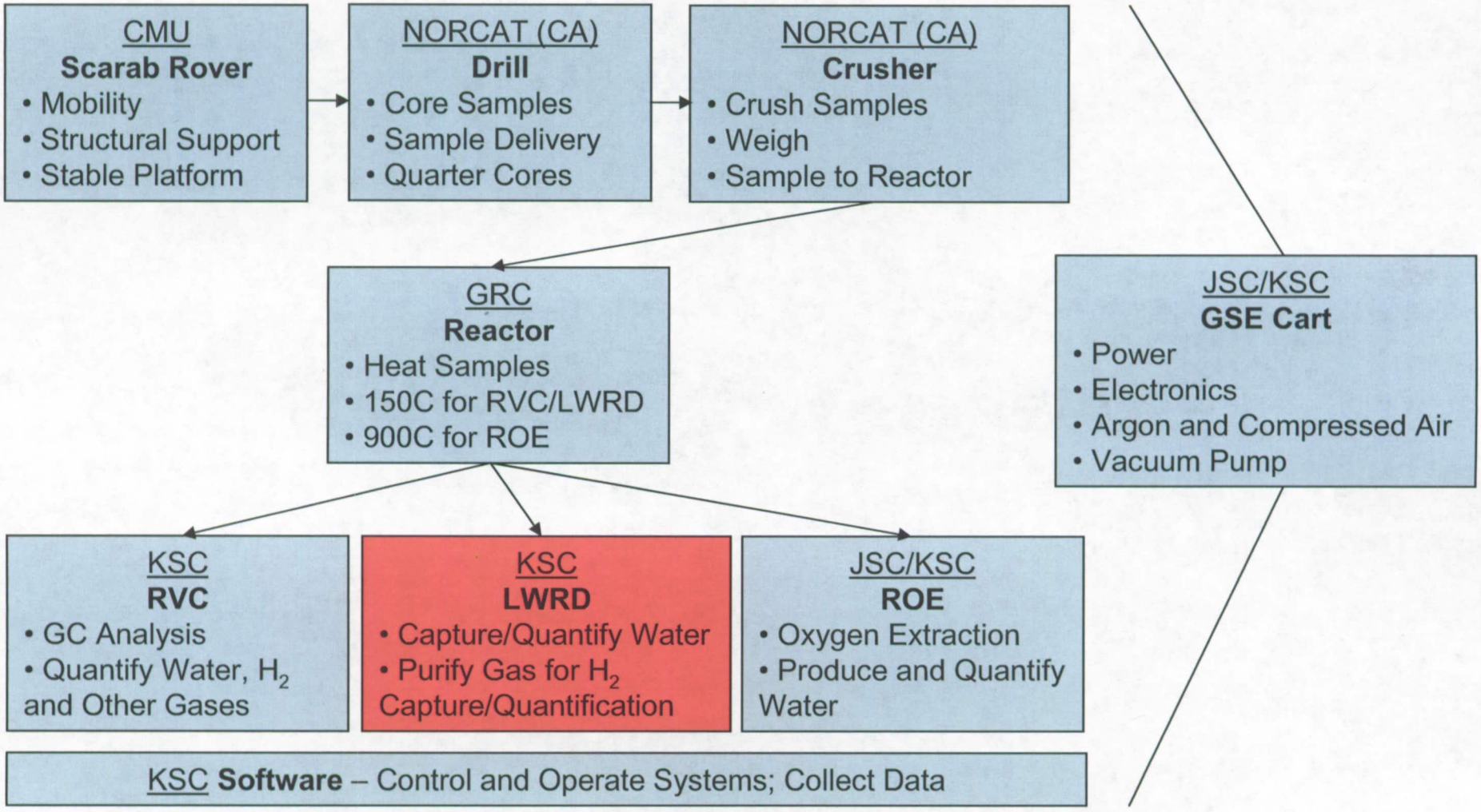
Outline

- **Background**
- **RESOLVE Project and Field Demonstration**
- **LWRD Key Design Requirements**
- **Design**
  - **Fluid systems**
  - **Water Bed**
  - **Other components**
  - **ProE 3-D model**
  - **Recirculation tests**
  - **Hydrogen bed calculations**
  - **Actual components**
- **Mass Reduction Strategy**
- **Power Estimate**
- **Planned Testing Deviations**
- **Schedule Update**
- **Relevance for Mars**
- **Summary**

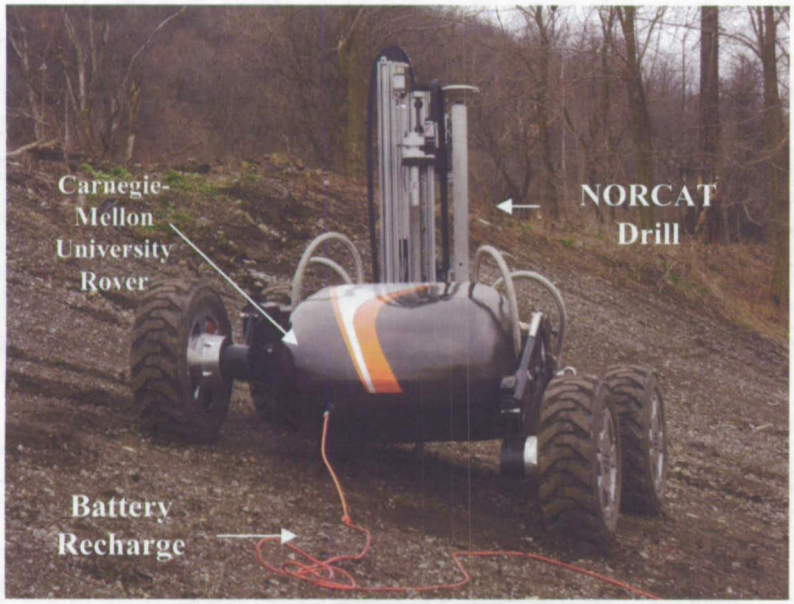
Background

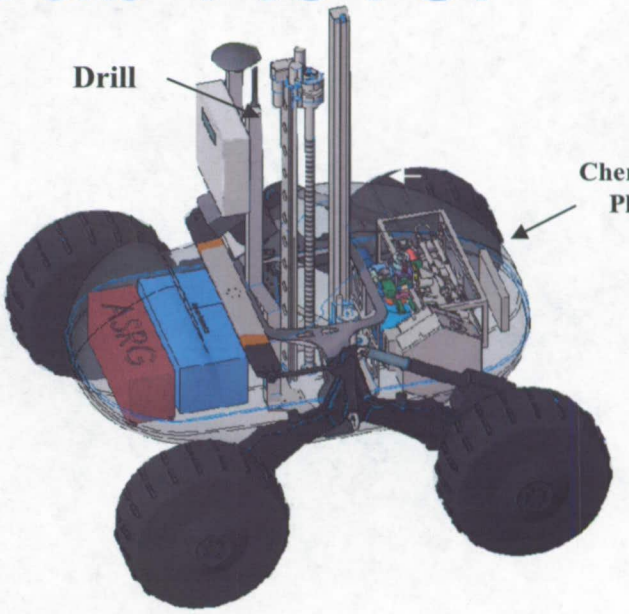
- LWRD is part of RESOLVE (Regolith and Environment Science & Oxygen and Lunar Volatile Extraction)
- RESOLVE is an ISRU ground demonstration:
  - A rover to explore a permanently shadowed crater at the south or north pole of the Moon
  - Drill core samples down to 1 meter
  - Heat the core samples to 150C
  - Analyze gases and capture water and/or hydrogen evolved
  - Use hydrogen reduction to extract oxygen from regolith
- The demo will take place on Mauna Kea as an analog site for the Moon (EBU2)
- JSC, GRC, KSC, NORCAT, CSA and CMU involved
- EBU1 established feasibility

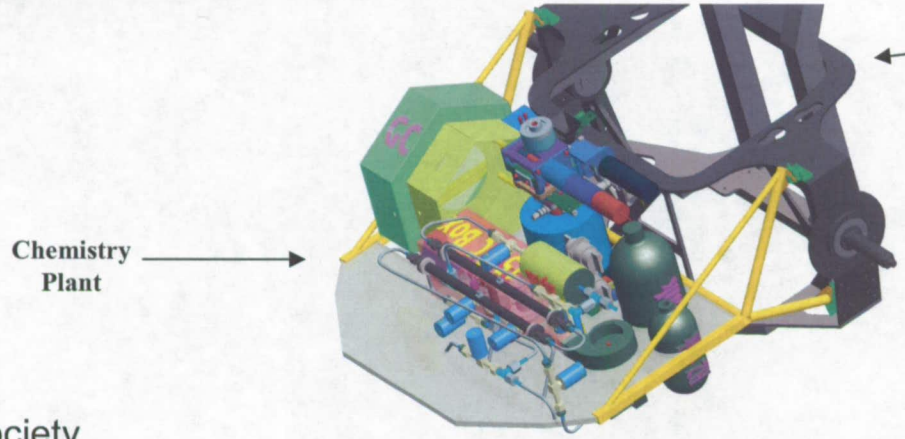
RESOLVE Block Diagram



RESOLVE/Scarab Rover



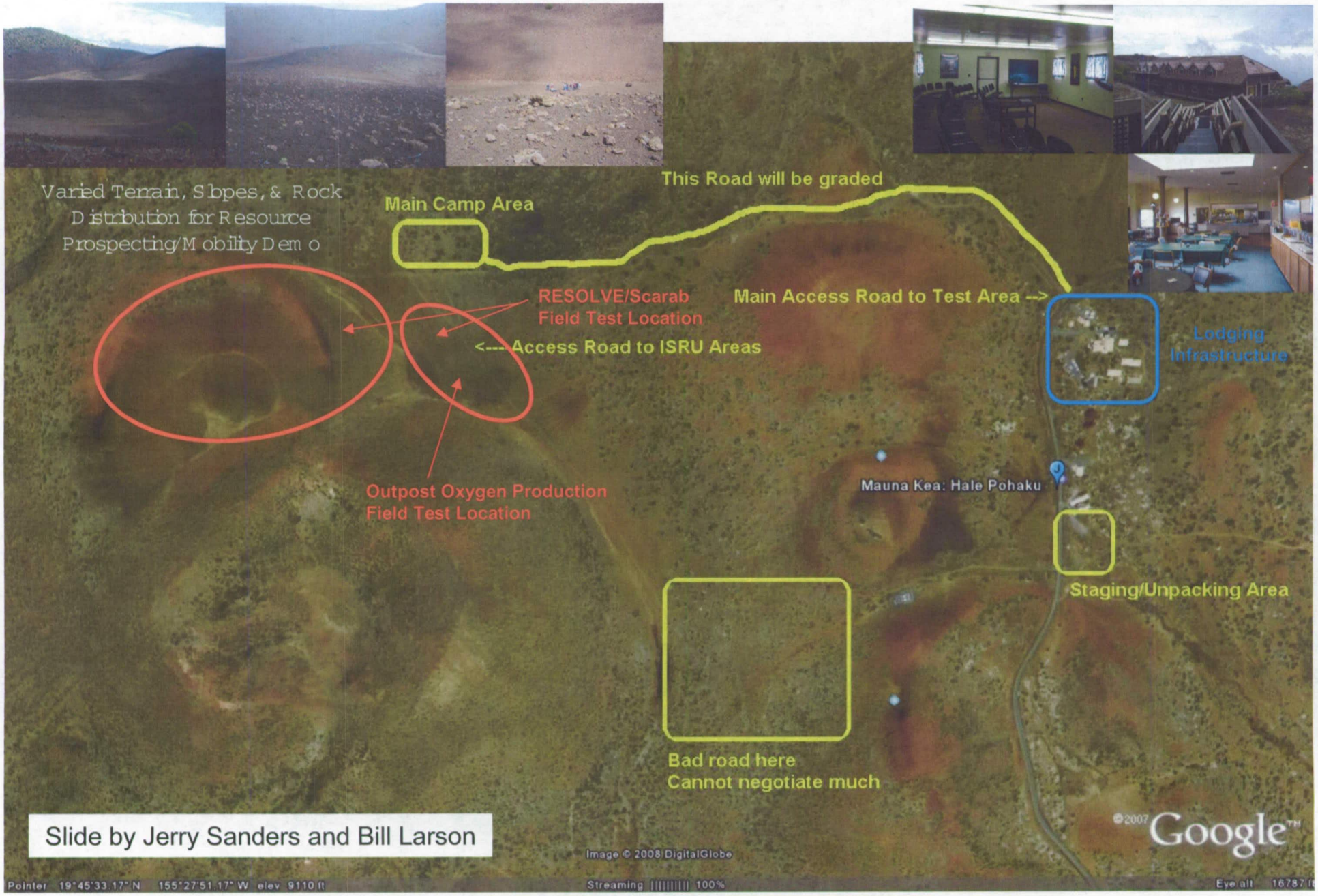




11th Mars Society
Convention

JOHN F. KENNEDY
SPACE CENTER

Nov. ISRU Field Test Infrastructure and Test Layout



Purpose of LWRD

- Capture up to 6 g of water per regolith/soil core sample and quantify up to 20 g of water (backup to GC measurements)
- Capture and quantify up to 0.15 g of hydrogen from same core sample (backup to GC measurements)

Key Design Requirements

- Prevent water condensation
  - Operate in 150C/130C Hot Boxes
  - Heated head recirculation pump
  - Heat trace Reactor gas lines
- Minimize number of transfers
  - 500 cc Surge Tank
- Absorb water at 130C
  - "Moisture Gone" zeolite absorbent
- Have sufficient water absorption capacity
- Quantify water
  - Desorption of MG is too slow; use RH probe, P, V, and T

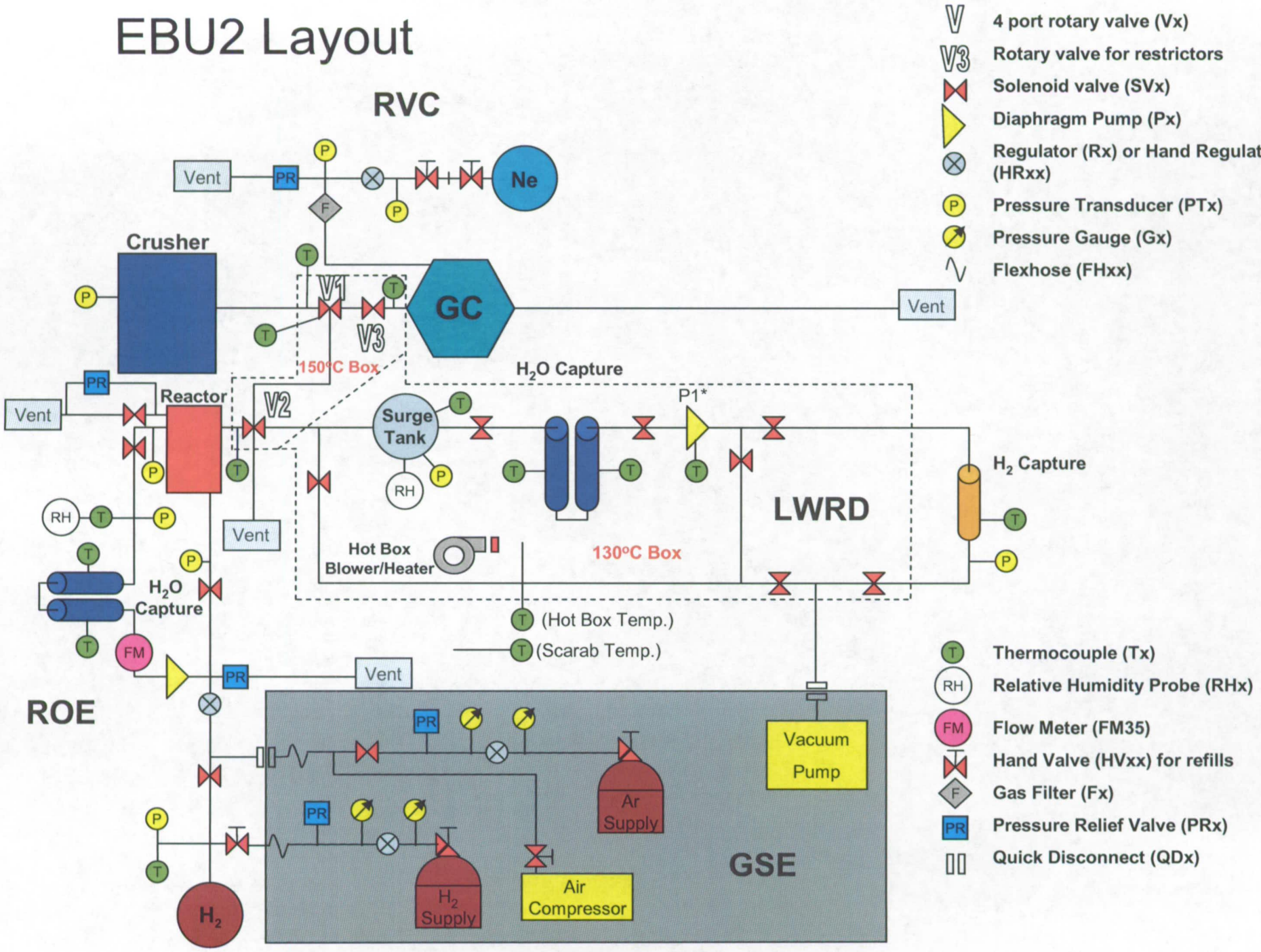
Key Design Requirements (Cont.)

- Absorb/desorb hydrogen efficiently
  - Florida Solar Energy Center developed new hydride former
  - Works at room temperature
- Operate during 8-12 hr workday
  - Desorb water beds overnight
  - Split full RESOLVE ops over two days
- Stay under 60 kg mass limit
  - Minimized masses of individual components
  - Transferred Ar, vacuum pump and electronics to GSE
- Demonstration on Mauna Kea in November 2008
  - Keep close track of schedule; resolve issues quickly
- Limited budget
  - Work efficiently; minimize equipment costs

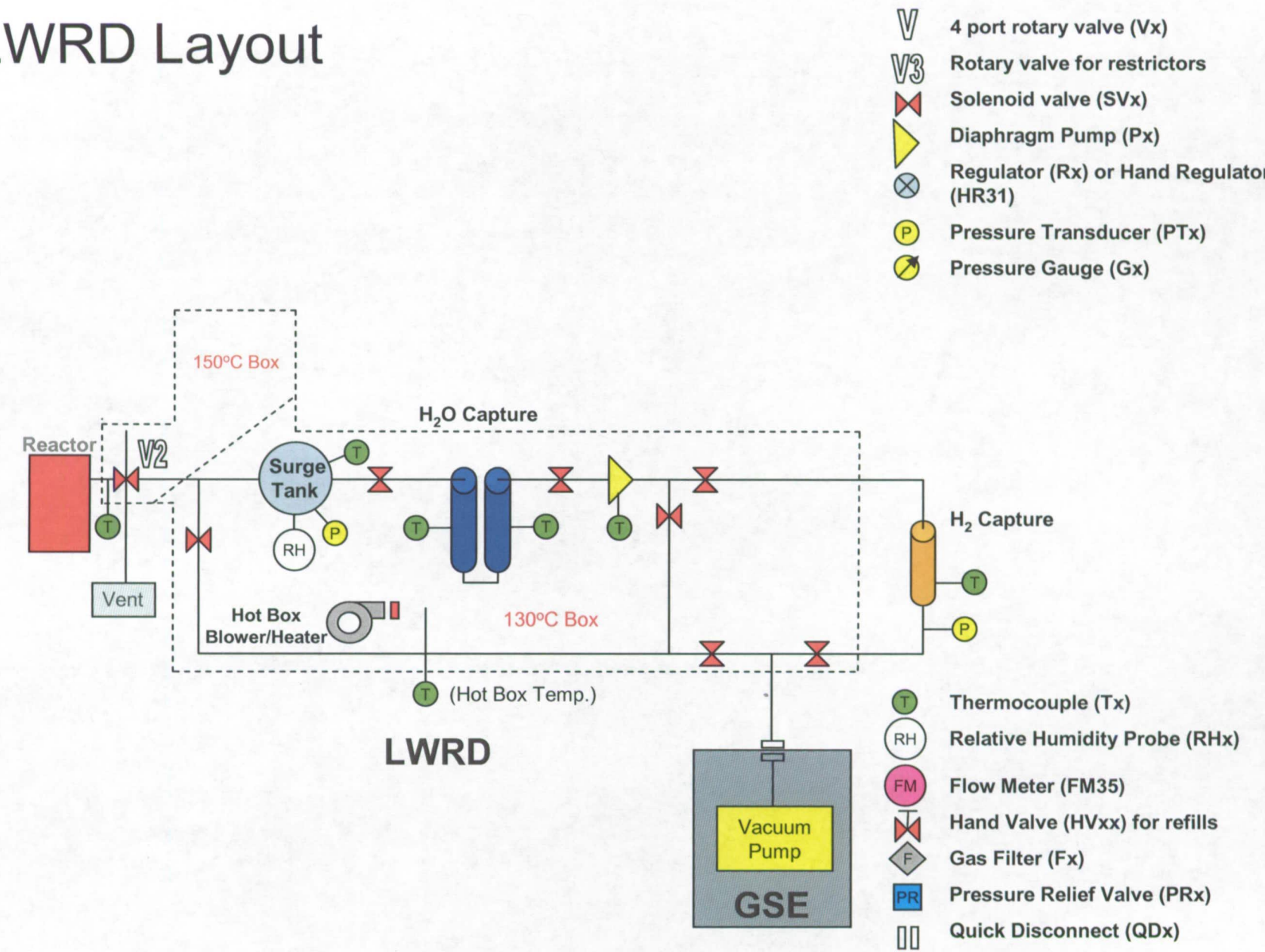
LWRD Process Summary

- At 150C in the Reactor, transfer gases to Surge Tank; measure RH, P, & T; and transfer to Water Beds two times (~1.5 g water)
- Transfer residual gases to Hydrogen Bed, vent unabsorbed gases, heat to 300C and measure P & T of desorbed gas in Surge Tank and H_2 Bed (skip this step in Hawaii demo)
- Subsequent transfers: measure RH, P, & T in Surge Tank since gases will consist of >90% water vapor; and vent
- Repeat sequence for each quarter core

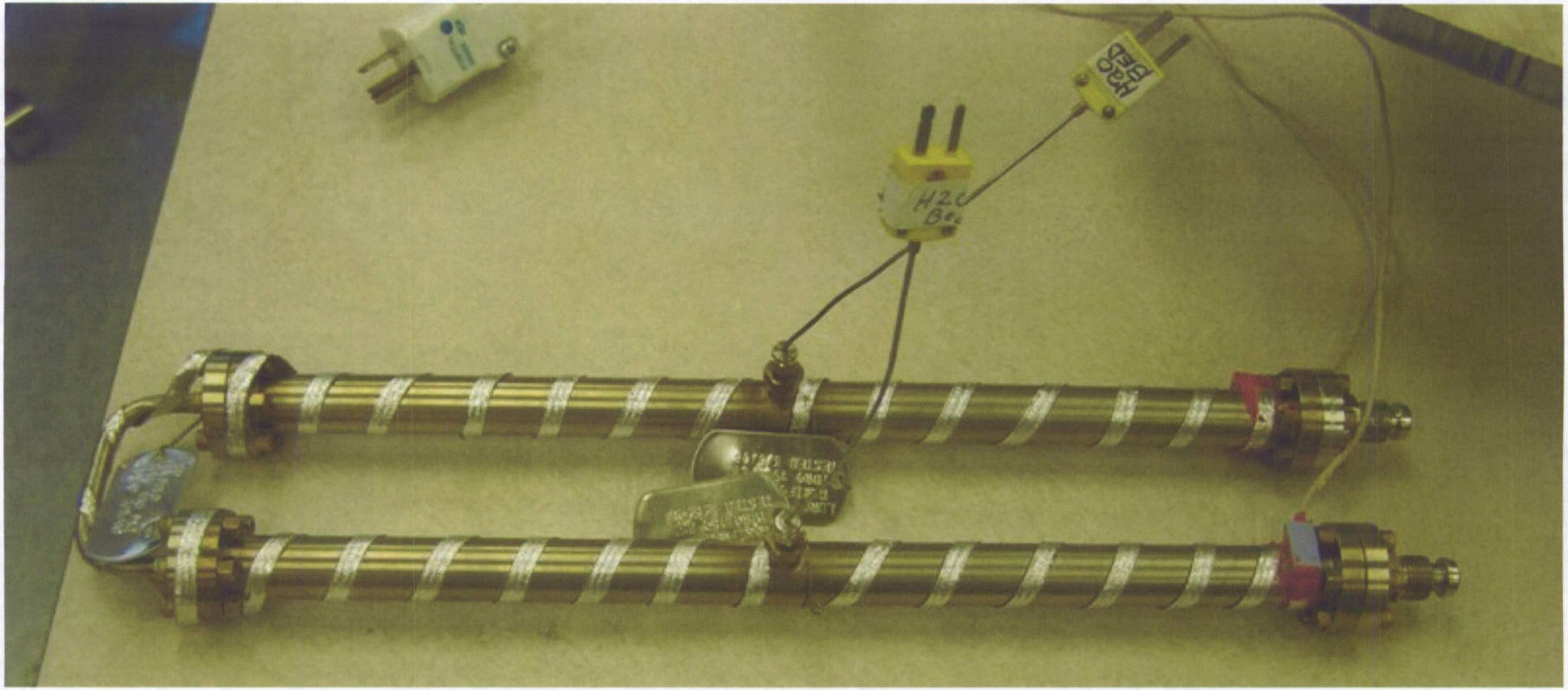
EBU2 Layout


RVC
Vent
PR
P
F
Ne
Crusher
T
V1
V3
GC
Vent
150°C Box
H2O Capture
PR
Vent
Reactor
V2
Surge Tank
P1*
RH
LWRD
H2 Capture
Hot Box Blower/Heater
130°C Box
H2O Capture
FM
(Hot Box Temp.)
(Scarab Temp.)
ROE
Vent
Vacuum Pump
Ar Supply
H2 Supply
Air Compressor
GSE
H2
4 port rotary valve (Vx)
Rotary valve for restrictors
Solenoid valve (SVx)
Diaphragm Pump (Px)
Regulator (Rx) or Hand Regulator (HRxx)
Pressure Transducer (PTx)
Pressure Gauge (Gx)
Flexhose (FHxx)
Thermocouple (Tx)
Relative Humidity Probe (RHx)
Flow Meter (FM35)
Hand Valve (HVxx) for refills
Gas Filter (Fx)
Pressure Relief Valve (PRx)
Quick Disconnect (QDx)

LWRD Layout


V
4 port rotary valve (Vx)
V3
Rotary valve for restrictors
Solenoid valve (SVx)
Diaphragm Pump (Px)
Regulator (Rx) or Hand Regulator (HR31)
P
Pressure Transducer (PTx)
Pressure Gauge (Gx)
150°C Box
H2O Capture
Reactor
V2
Surge Tank
T
RH
P
Vent
Hot Box Blower/Heater
130°C Box
H2 Capture
(Hot Box Temp.)
LWRD
Vacuum Pump
GSE
Thermocouple (Tx)
Relative Humidity Probe (RHx)
FM
Flow Meter (FM35)
Hand Valve (HVxx) for refills
F
Gas Filter (Fx)
PR
Pressure Relief Valve (PRx)
Quick Disconnect (QDx)

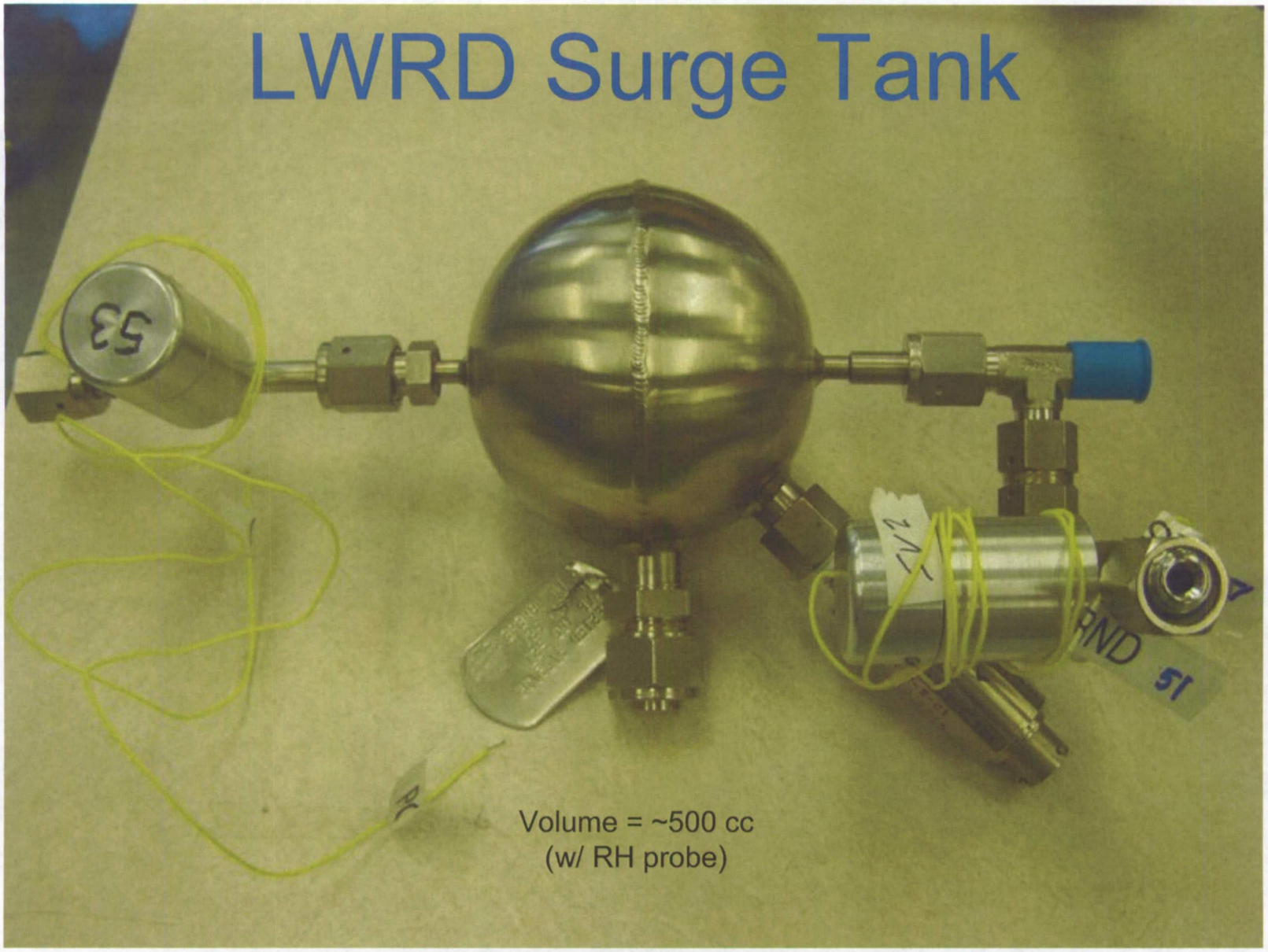
Mark I Water Beds



Capacitance Water Beds

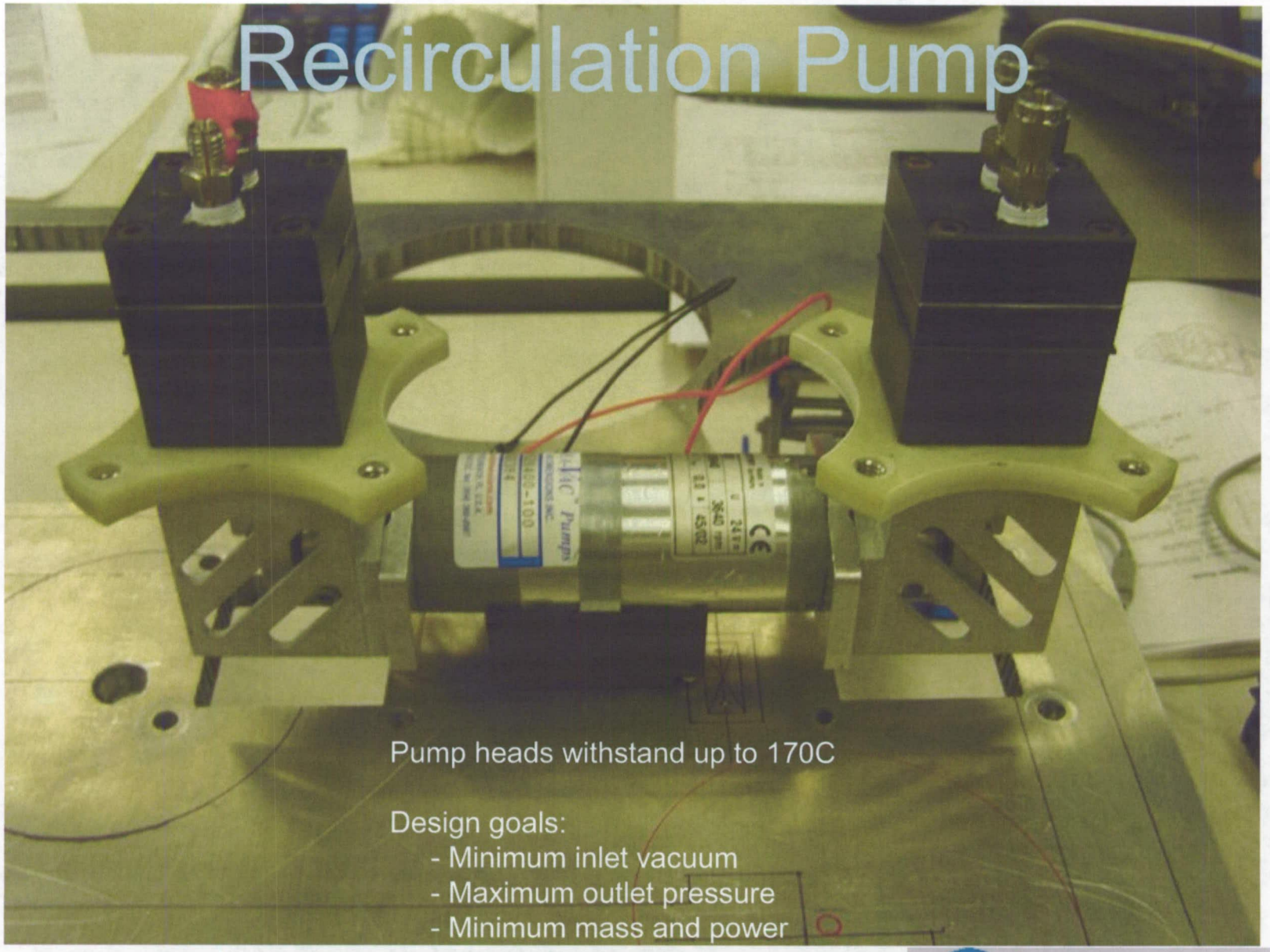
- Developing Mark III water beds to measure water uptake using capacitance measurements
- Testing underway
- Will be used on ROE along with RH probe and flow meter to advance the technology
- Won't depend on capacitance measurements until sure of accuracy

LWRD Surge Tank



Volume = ~500 cc
(w/ RH probe)

Recirculation Pump

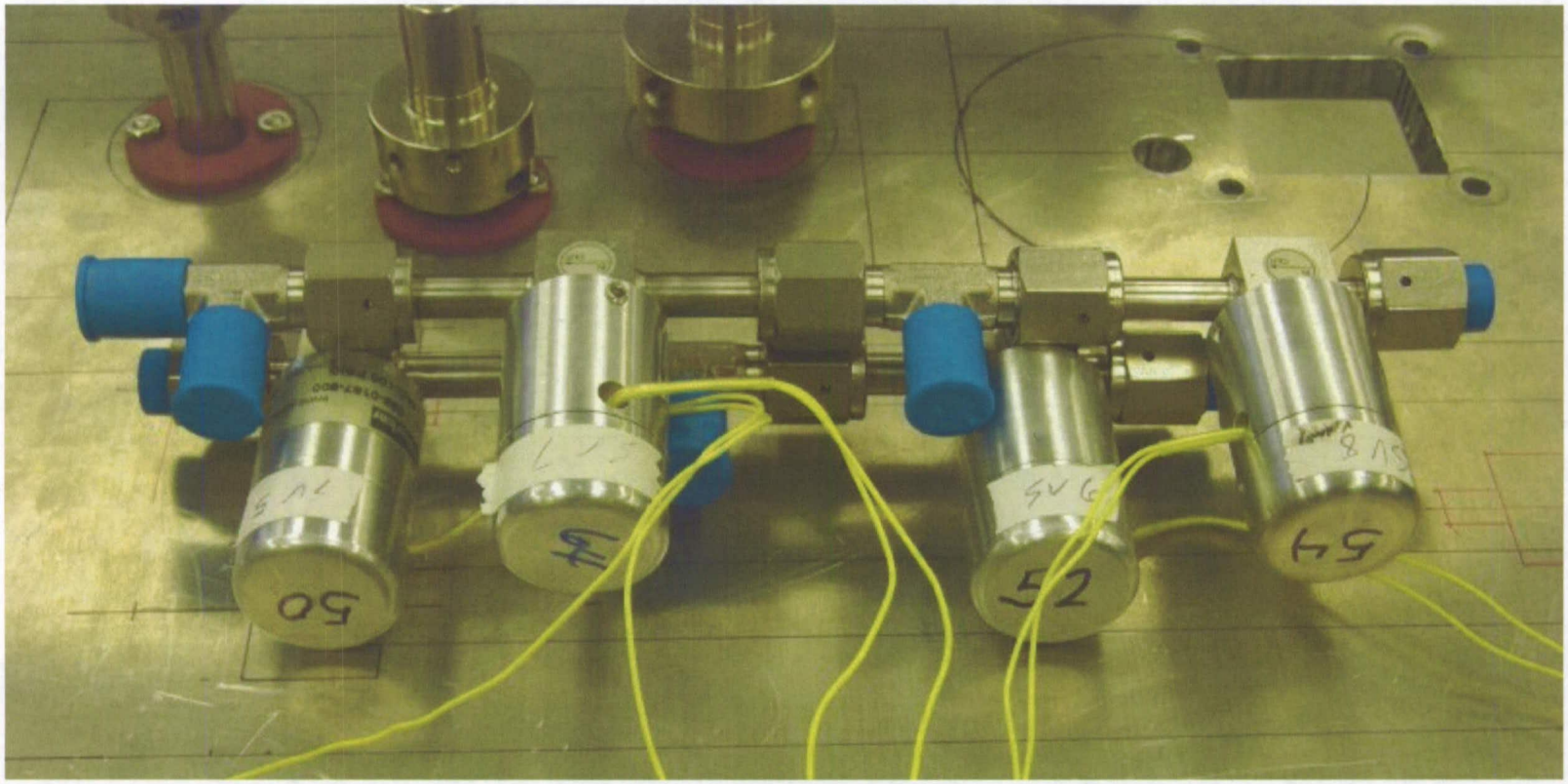


Pump heads withstand up to 170C

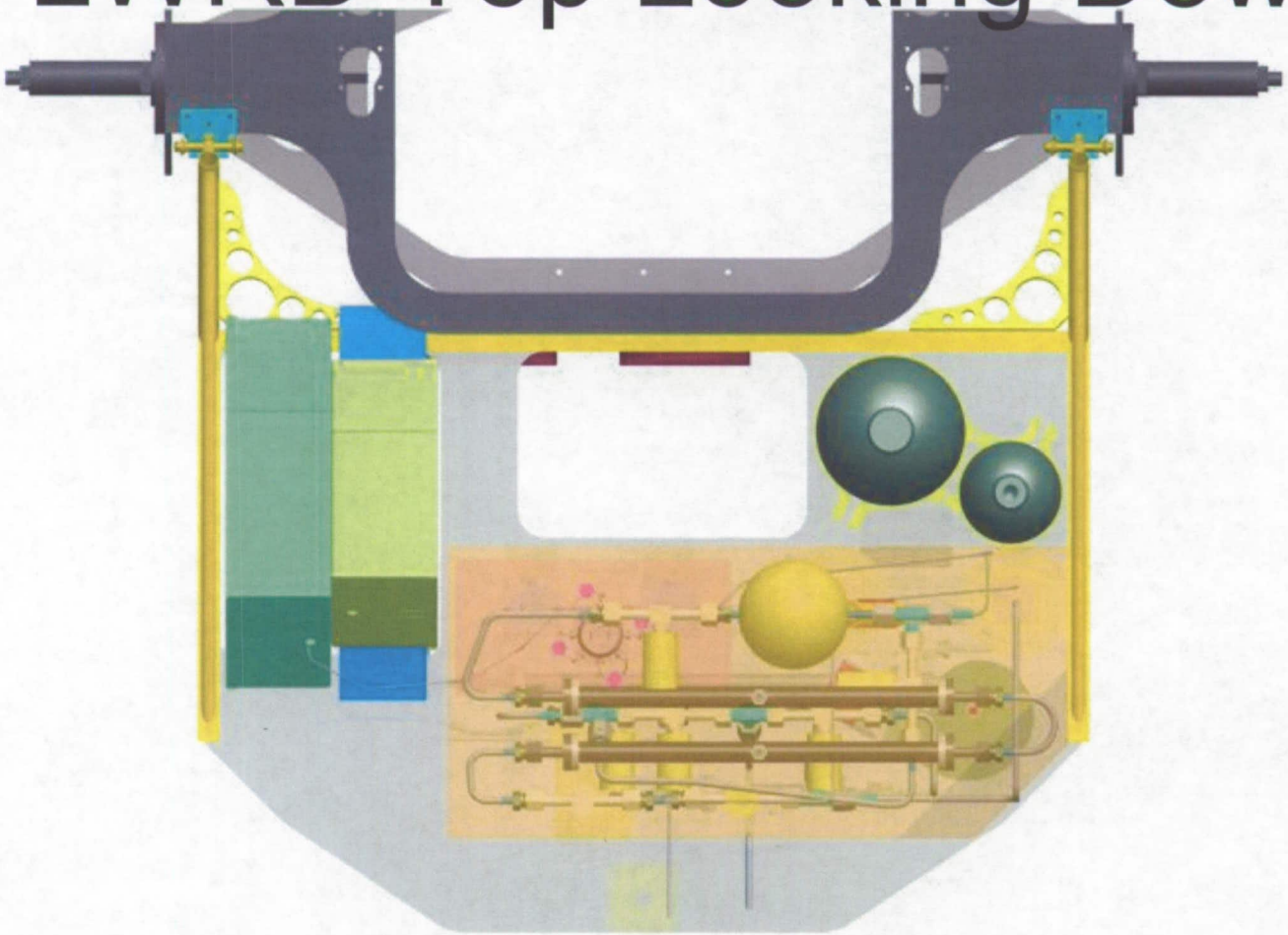
Design goals:

- Minimum inlet vacuum
- Maximum outlet pressure
- Minimum mass and power

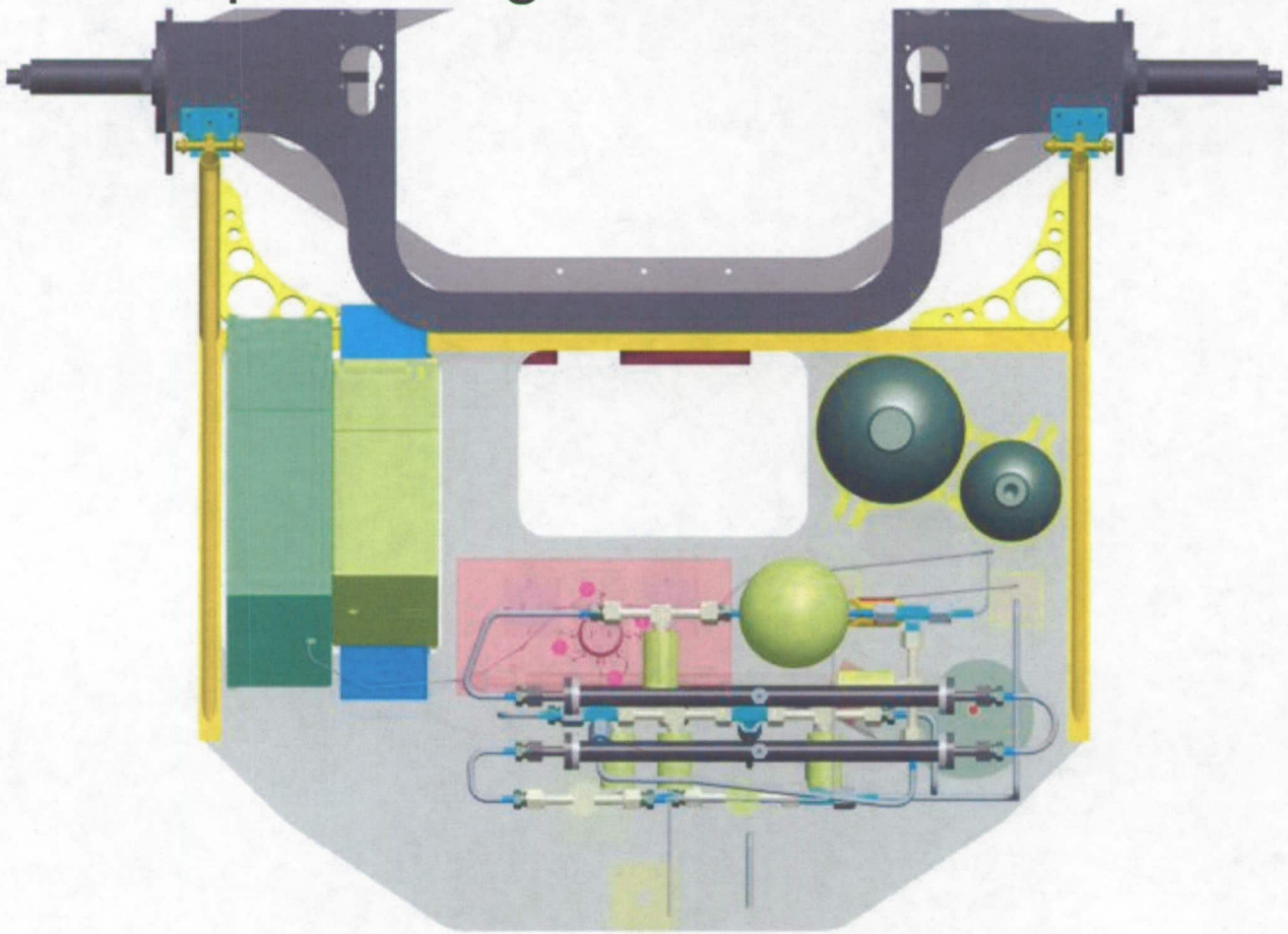
High Temperature Latching Solenoid Valves



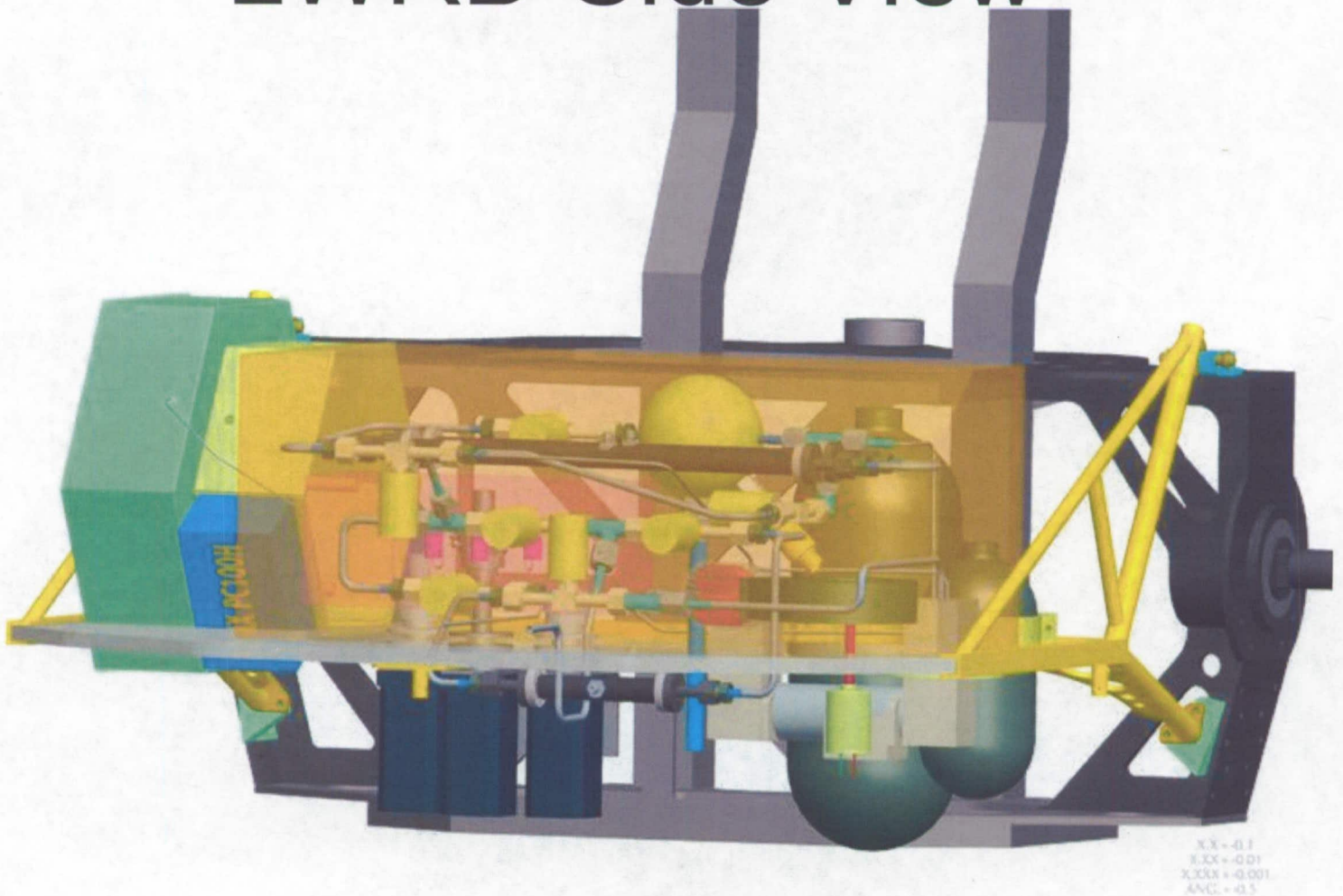
LWRD Top Looking Down



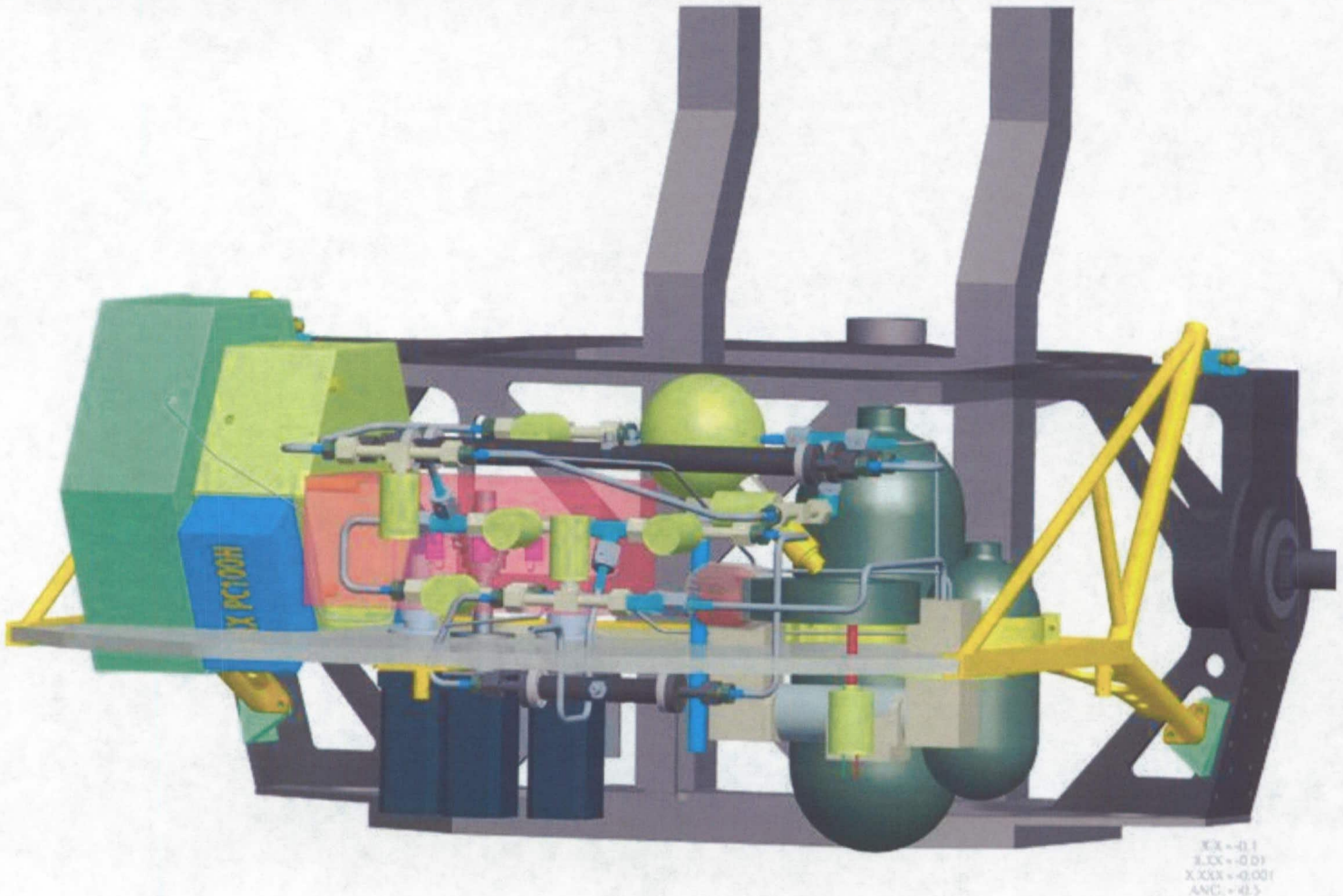
LWRD Top Looking Down – 130C Box Removed



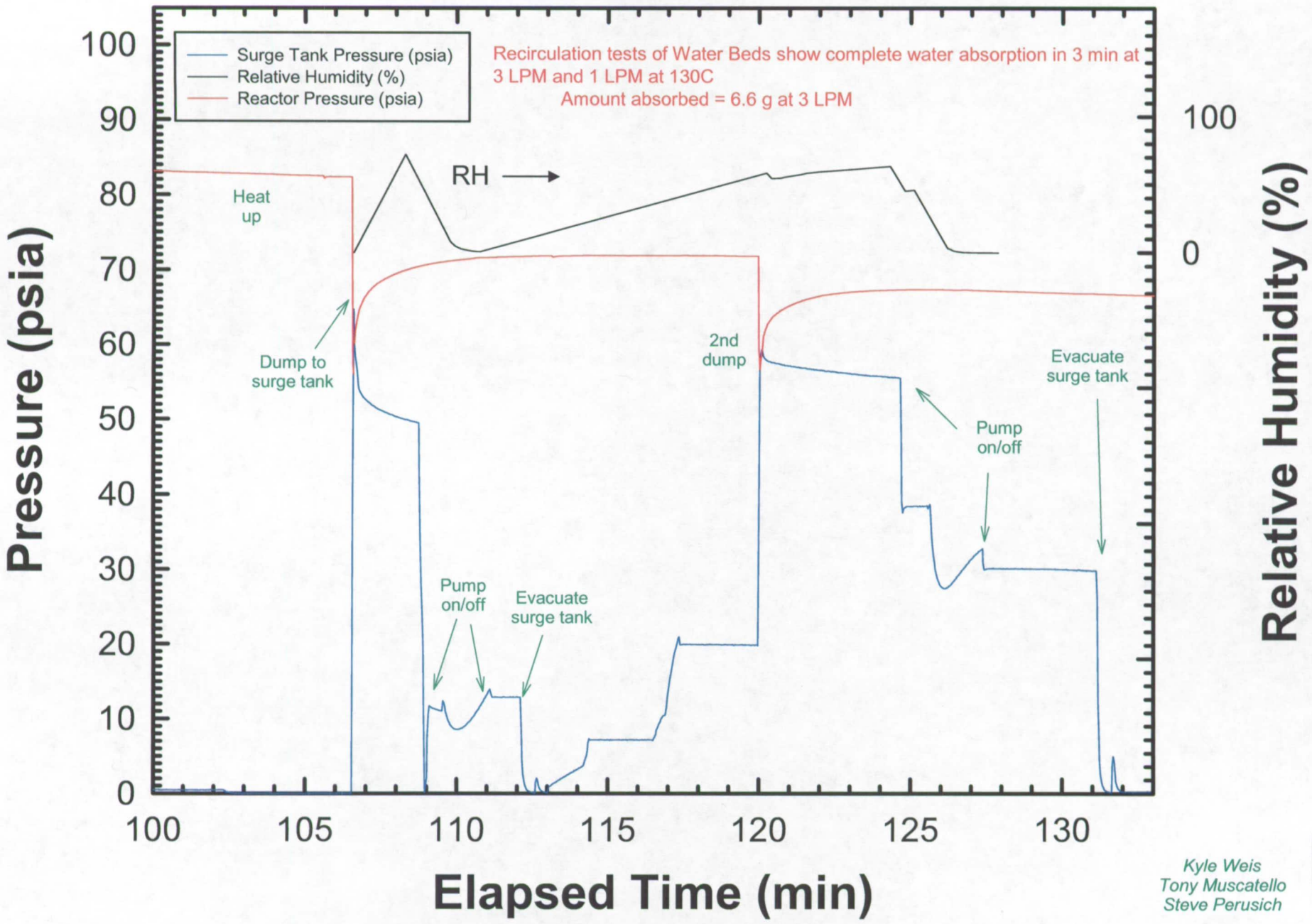
LWRD Side View



LWRD Side View – 130C Box Removed



Flow Recirculation (4/24/08)



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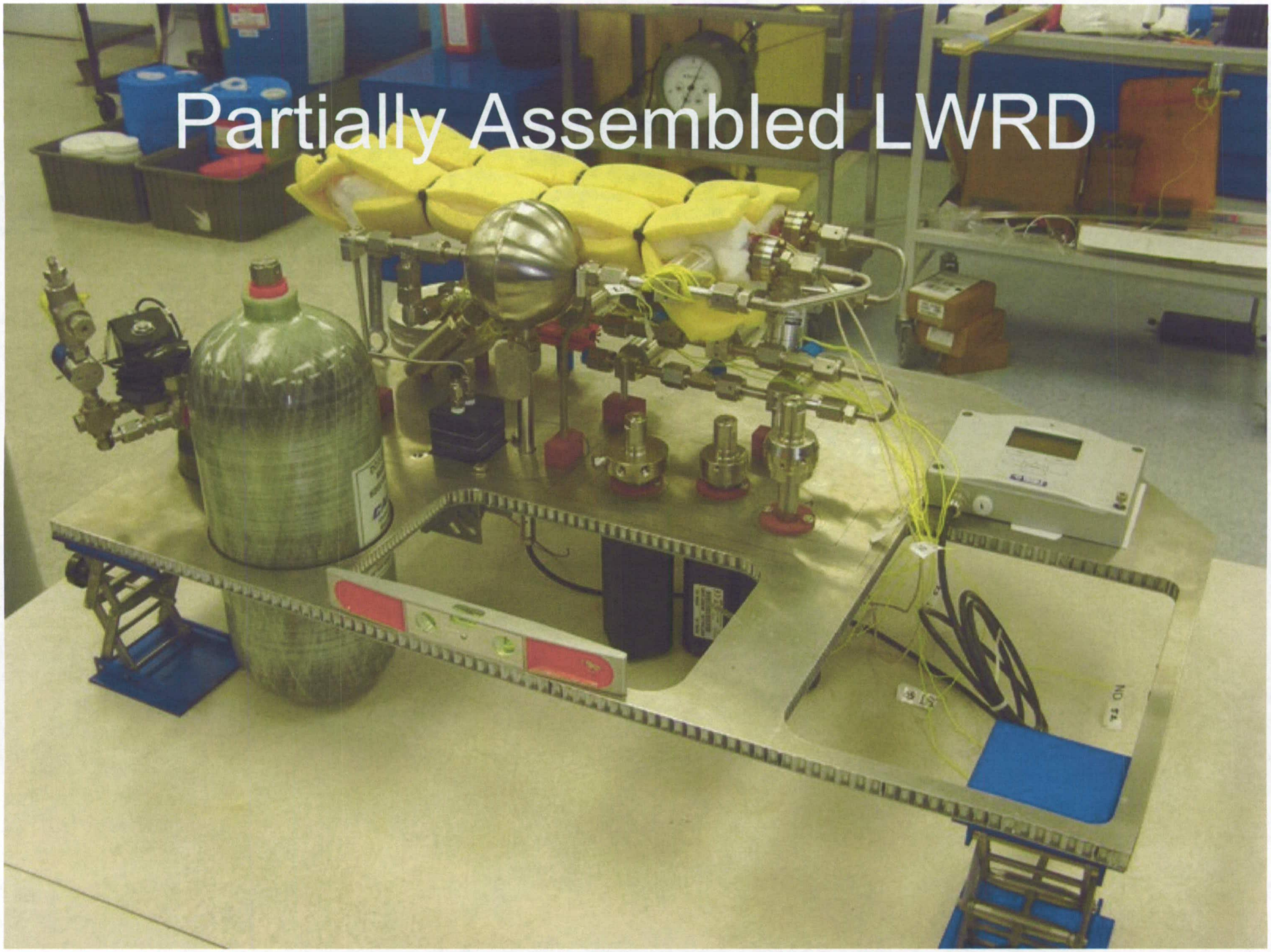
Hydrogen Desorption

- H_2 Bed capacity = 79 g of new absorber
- Absorber capacity = 0.15 g (0.2%)
- Free bed volume = 13.9 cc
- Delta P at 300C = 4000 psi (rated at 150 psi) + equilibrium like water bed desorption
- Therefore, use Surge Tank; Delta P = 74 psi
- Encourages dehydriding to completion


Partially Assembled LWRD

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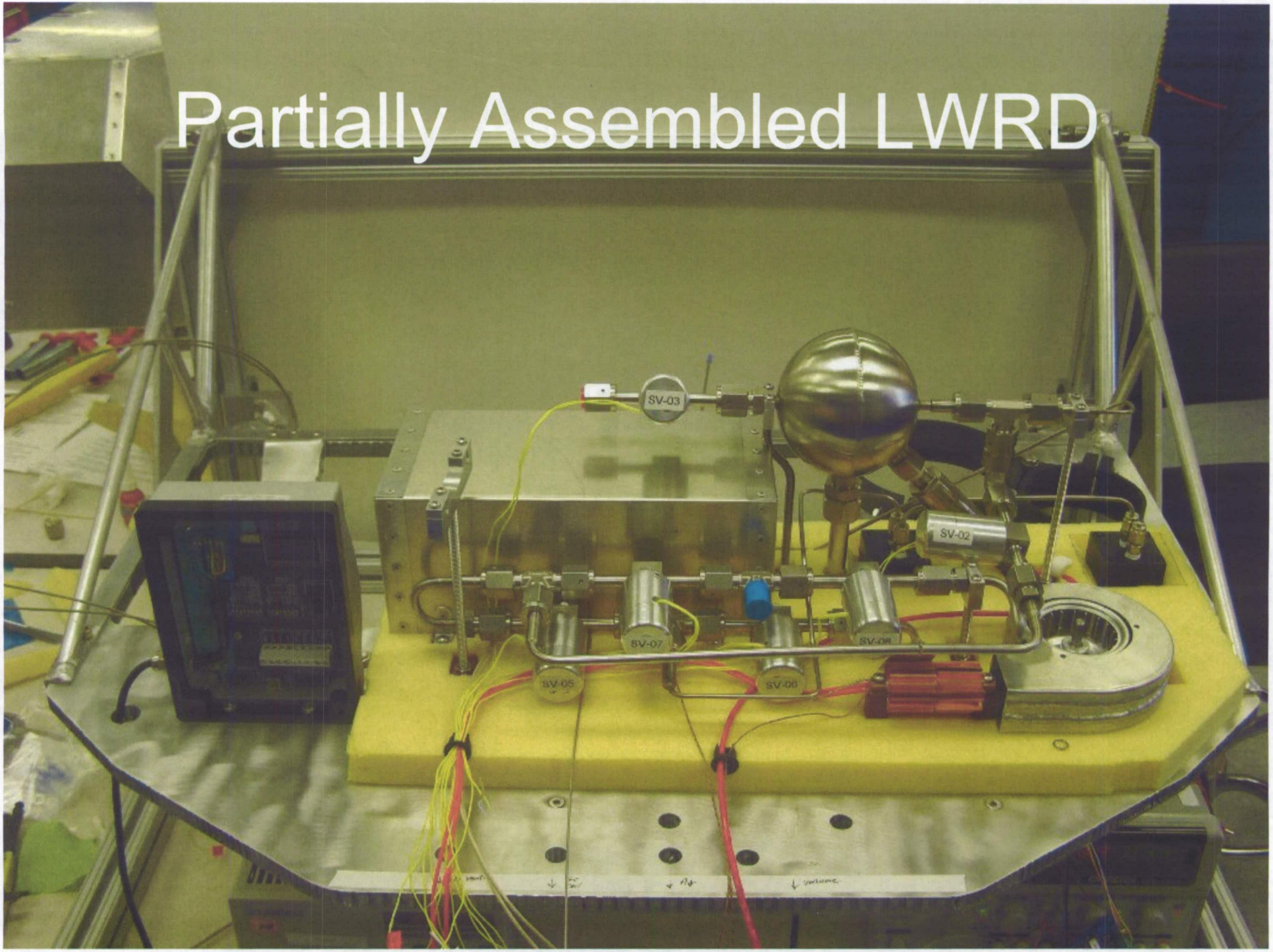
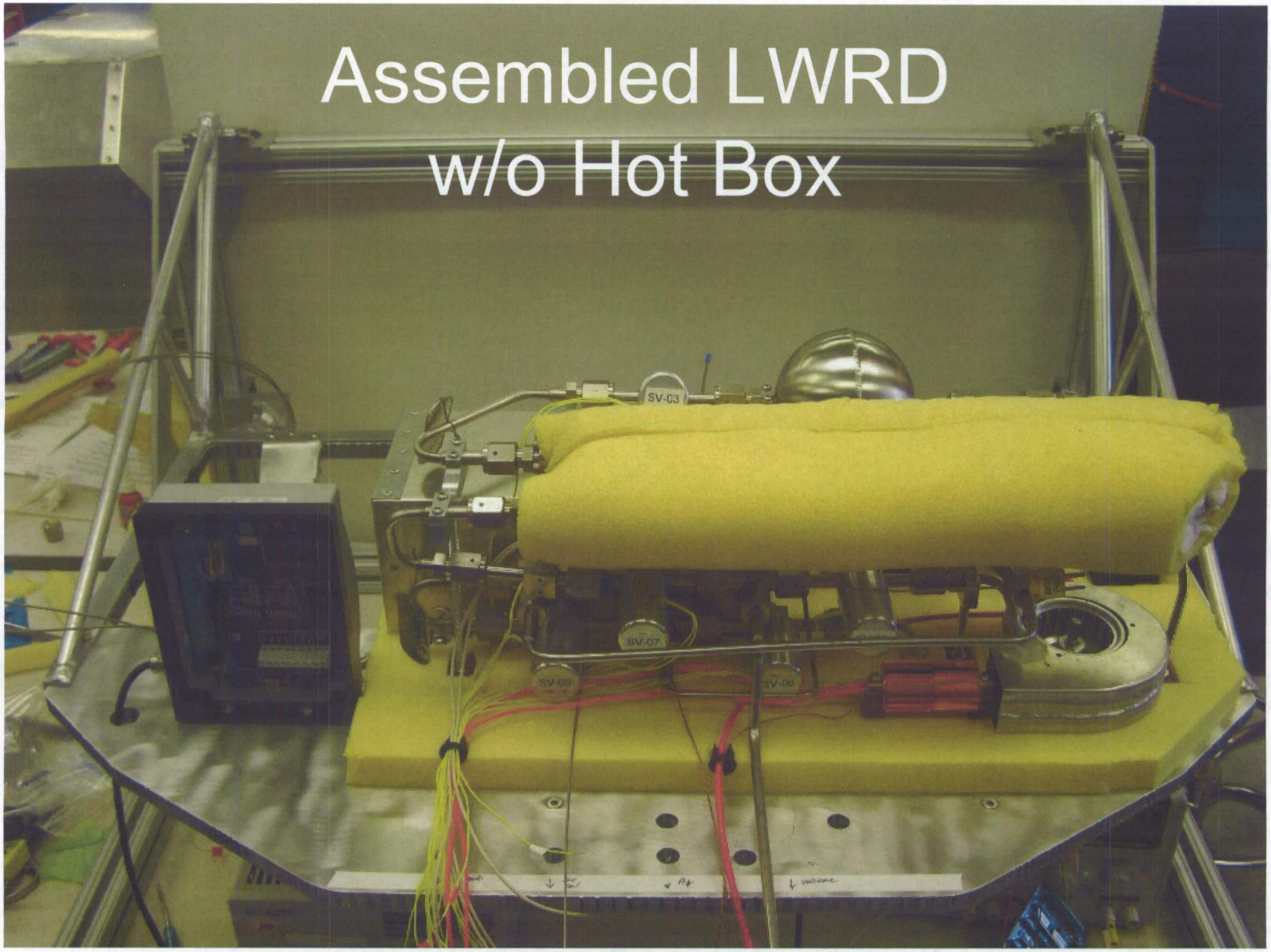
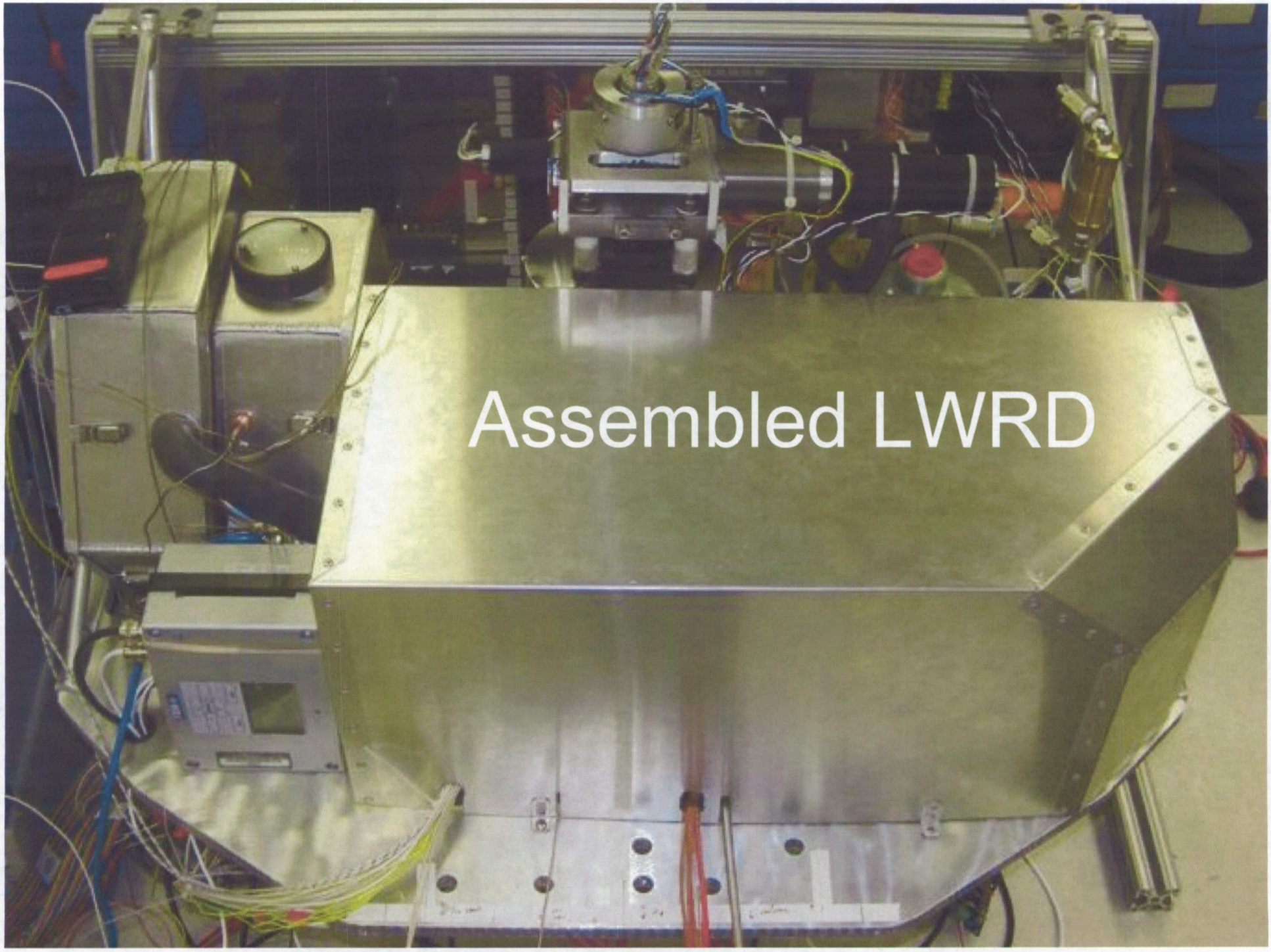
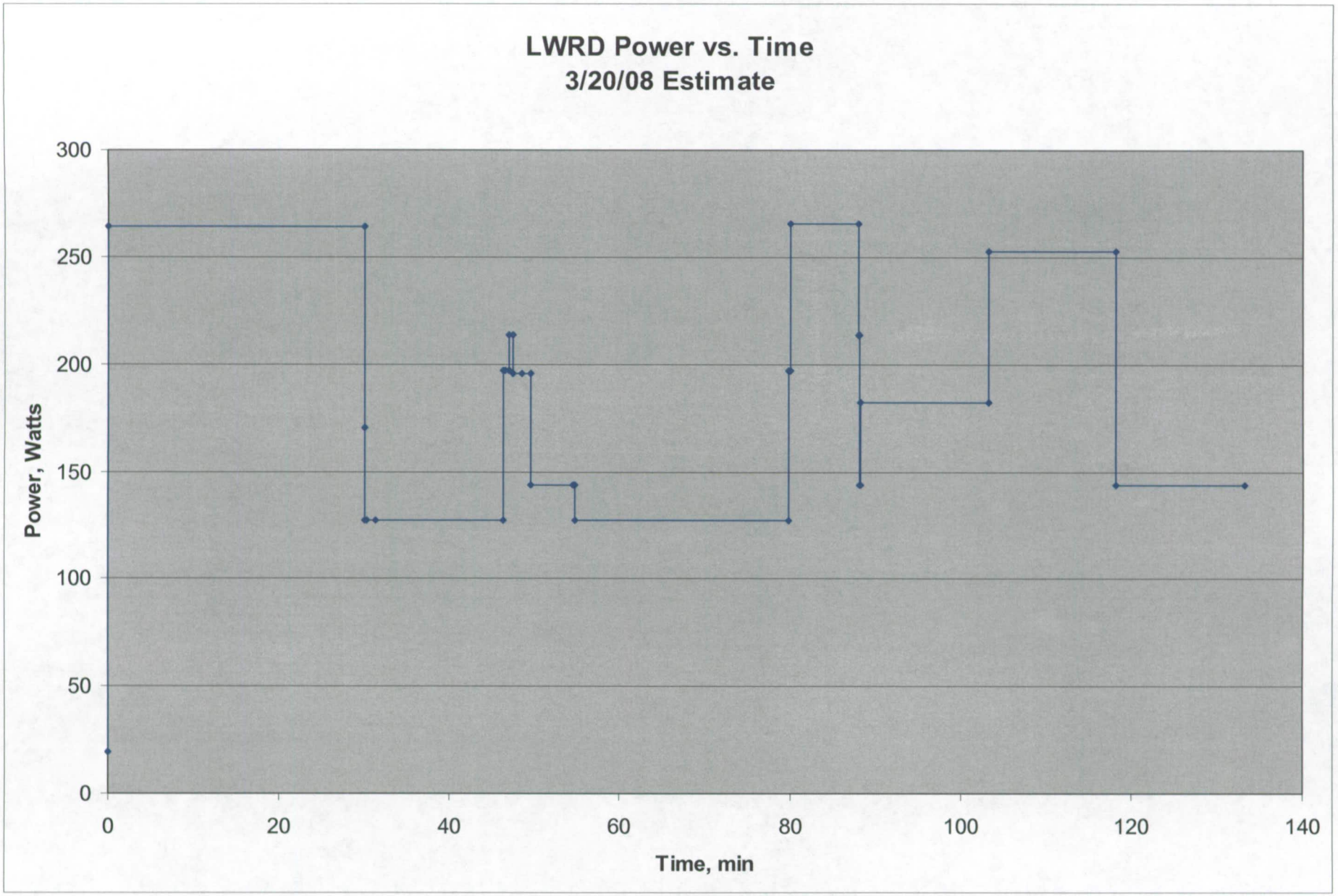



Assembled LWRD
w/o Hot Box
SV-03
SV-07


Assembled LWRD

Mass Reduction Strategy

- Construct the system as planned with 1.4 kg of mass savings available from removal of one ROE water bed and the hydrogen bed during the demo if needed.
- Keep the neon and hydrogen tanks on the rover.
- Once everything is constructed and we have actual masses, remove those tanks if necessary (-3.8 kg).


LWRD Power vs. Time
3/20/08 Estimate
Power, Watts
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140
Time, min

Planned Testing Deviations

- Lab – full capabilities demonstration
- Hawaii – no hydrogen absorption/ desorption/quantification demonstration

Schedule Update

LWRD/RESOLVE Tasks	Planned Start Date	Planned Finish Date
Complete final design	Thu 1/31/08	Fri 2/15/08 Complete
Order/Make Long Lead Items	Tue 2/5/08	Fri 2/29/08 Complete
All parts received or made	Mon 3/31/08	Mon 3/31/08 Complete
Component Assembly and Testing	Mon 2/18/08	Tue 4/15/08 Complete
RESOLVE Volume Simulator Design to CMU	Sat 3/15/08	Sat 3/15/08 Completed on time Volume Simulator Also Shipped 5/1/08
Mount RVC/LWRD in Hot Box and Warm Box	Wed 4/16/08	Wed 4/30/08 Complete
Go/No Go Decision for Capacitance Sensor	Wed 4/30/08	Wed 4/30/08 No Go for Now Will add to ROE
RVC/LWRD Test Matrix	Thu 5/1/08	Fri 5/30/08 Awaiting assembly
Deliver Tested RVC/LWRD	Sun 6/1/08	Sun 6/1/08 Subsystem complete. Testing on full system only.
RESOLVE Integration and Testing at KSC	Mon 7/1/08	Mon 9/8/08 Underway
Shipping, Integration w/Rover, Testing at CMU	Tue 9/9/08	Tue 9/30/08
Ship to Hawaii	Mon 10/27/08	Fri 10/30/08
Field Test on Mauna Kea	Sat 11/1/08	Wed 11/12/08

Relevance for Mars

- RESOLVE could be used to find and characterize Mars ice
  - Mobile, unlike Mars Phoenix
  - Drill better than scraper (IMHO)
- Lunar ice can be electrolyzed into hydrogen and oxygen propellant
  - Very useful if sent to LEO for Mars missions
  - Refill fuel tanks and go!
  - Could save $billions

Summary

- LWRD Team has accomplished major goals in design and construction
- Redesigned compared to EBU1 because of changes in assumptions and requirements
- Expect to be ready for November demo in Hawaii